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ANALYSIS OF GROUND CALIBRATION DATA FROM STRAIN GAUGES ATTACHED--ETC(U)

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ANALYSIS OF GROUND CALIBRATION DATA FROM STRAIN GAUGES ATTACHED TO THE AIRFRAME OF CT4A AIRTRAINER A19-031.

M.G.J. HIGGS

Approved for Public Release.

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SUMMARY

A CT4A Airtrainer airframe has been subjected to wing bending, wing torque, fin loading and tailplane loading.

The resulting strains are analysed herein.

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16. ABSTRACT:

A CT4A Airtrainer airframe has been subjected to wing bending, wing torque, fin loading and tailplane loading.

The resulting strains are analysed herein.

CONTENTS

1. INTRODUCTION

As a preliminary to full scale fatigue testing, an RAAF CT4A Airtrainer has been ground calibrated at ARL. The analysis of the resulting strain gauge data is presented here.

2. SUMMARY OF TEST PROCEDURE

The ground calibration procedure is briefly summarised here.

Strain gauges fitted to various positions on the aircraft were used to obtain the strain responses for four loading cases. These were wing bending, wing torque, fin loading and tailplane loading. The gauge positions are shown in figure 1.

For loading purposes, the test aircraft was bolted to the floor at the nose undercarriage leg attachment point and at the rear cockpit (approximate fuselage station 3810 mm.). These constraints provided a high degree of rigidity in the vertical plane, and also some rigidity in rolling.

Wing bending loading was distributed over the wing surface through whiffle trees and applied to the wing by contour boards at alternate ribs (wing stations 940, 1410, 1943, 2477, 3010 and 3543 mm.). Half-wing weights estimated at 90 kg, and weights of whiffle trees, contour boards and hangers totalling 500 kg per side were balanced out. The zero g condition was estimated to correspond to a net downward load of 32 kg per side and the incremental load per g was calculated to be 298 kg. Torque loads were also applied through the same system with additional loads at the same stations at the leading and trailing edges. Loading distributions were estimated from the manufacturer's design data assuming an aircraft all up weight of 1090 kg.

When applying fin loads, the rudder was removed and single point loading was applied at the top hinge point. For tailplane loading, the elevators were removed and single point loads were applied at the outboard hinge points.

General views of the loading rig are shown in figs. 2(a) and (b).

For all cases except wing bending, the loading cycle (called a 'run') is illustrated in figure 3 and consisted of:-

(a) Loading in prescribed increments in the negative direction from the reference condition, (called 0% maximum calibrated load, or m.c.l.) to 100% m.c.l.

(b) Unloading to the reference condition using the same increments.

(c) Repeating (a) in the positive direction

(d) " (b) " " "

The prescribed increments were 20% m.c.l. For wing bending, loading was applied as in (a) to (d) above, but data was not recorded during either (a) or (d). The load increments were nominally 12.5% m.c.l.

Table 1 summarises the loading details. It is noted that several runs were applied for each case.

3. DATA RECORDING AND ANALYSIS

Table 2 gives the recording channel numbers for the strain gauges and other transducers fitted to the aircraft. The other transducers occupied channels 1 to 15 and 48 to 50: these were not relevant to the ground calibration. Also the strain gauges fitted to the flap mechanisms (channels 26 and 27) were not used in the ground calibration.

The calibration data were recorded as files on magnetic tape. A data file consisted of a number of blocks, each of which contained an identifier and 50 channels of output. The program CT4Z, (in Fortran IV), read this data and computed the linear regression statistics for each channel for:-

(a) Either the loading or unloading phase of one 'half run' (the half run being defined as loading and unloading in one direction only).

(b) Either the loading or unloading phases of more than one half run in a given direction (i.e. (a) combined over all runs).

(c) As for (b), but with loading and unloading phases combined.

(d) The loading and unloading phases in both directions combined over all runs.

The regressed variable, y, was in microstrain units

$$y = [S_{ref} - S_{mes}].F$$

where S_{ref} = reference strain (in computer units, c.u.)

S_{mes} = measured strain (c.u.)

F = strain calibration factor #1

#1 For converting computer units to microstrain, see Table 3.

The linear regression analysis examined the significance of slope and offset variations between calibration loading runs of the same type.

4 INTERPRETATION OF RESULTS

4.1 WING BENDING

The wing bending gauge responses are presented in Table 4, which gives the strain increments based on the regression slopes for y on x, (as defined above), for each calibration loading.

Table 4 also compares the average total increment in the range -1 to +3g derived from the average linear regression expressions against the 'mean increment' defined as

$$\sum_{i=1}^{n} [c_{ij}(100) - c_{ij}(-100)].F_j/n$$

where $c_{ij}(100)$, $c_{ij}(-100)$ = the c.u. at +3g and -1g respectively

j = channel no.

i = run no.

n = number of runs

and F_j = strain calibration factor for j^{th} channel

The main spar gauges, (other than 2BE), gave the highest outputs of more than 180ue/g. The port and starboard equivalent gauges gave consistent outputs in most cases, the exceptions being stations 21SE and 22SE where the gauge outputs, (for 200% m.c.l.), were in the ratio of 0.55:1.

4.2 WING TORQUE

It was apparent from the strains measured during wing torque loading that considerable hysteresis occurred after change of direction of applied load. Strain gauge responses for the torque loading cases are shown in Tables 5(a) - (d). Tables 6(a) - (b) show the change of offset during each half run, which was evaluated to provide a measure of hysteresis.

The torque loading case applied a bending moment in addition to a pure torque. This moment included the 1.0g symmetric wing bending load, in addition to bending moment associated with the incremental torque loading. It is possible to derive the strain due to pure torque by subtracting the known bending moment response from the response to the combined loading case. This

was carried out using the procedure described in appendix 1. The derived strains attributed to pure torque are shown in Table 7. As one would expect, the strains in the main spar were very small. The most significant strain was measured at gauge 30SE at the rear of the root rib. The strains in Tables 6(a) and (b) may also be influenced by the 1g bending load cycle.

4.3 FIN LOADS

Strain increments derived from fin loading (for both +'ve and -'ve calibrations) are given in Tables 8(a) - (d). Fin spar gauges have significant response but longerons were not so. For gauges 33TE and 34TE, compression response is consistently greater than the tension response. Fin loading produced the largest hysteresis which is clearly illustrated in figure 4 where the gauge output, (microstrain), has been plotted against % m.c.l. for strain gauge 33TE. Also Tables 9(a) and (b) give the change of offset between the loading and unloading phases for the positive and negative calibrations.

Outputs from the fin strain gauges 33TE and 34TE for the loading phases of all runs are plotted in figure 5, which shows reasonable linearity and repeatibility between runs in spite of the hysteresis. The plotted microstrain values were obtained after subtracting the offset for the run concerned.

4.4 TAILPLANE LOADS

The tailplane loading case, (see Tables 10(a) - (d)), gave the least variation in gauge response between runs of all load cases, but the response of gauges 37BE and 38BE was greater for up loading than for down loading. The outputs from all gauges were non-linear; the symmetric port and starboard gauges indicated slight asymmetry in loading. Responses of gauges 36BE, 37BE and 38BE for run 1 are shown in figures 6(a) - (c).

The change of offset between loading and unloading phases is shown in Tables 11(a) - (b). Values are usually consistent.

5 CONCLUSIONS

Relationships between strains and wing bending, fin and tailplane loads have been measured and relationships between strains and pure torque derived from the combined torque/bending moment case.

From the analysis it is concluded that:

(a) Measured strains in the centre and inboard sections of the main spar (5BE, 9BE, 12BE, 10BE, and 6BE), are substantially higher than elsewhere.

(b) For the wing bending load case, the strain vs. load slopes showed significant differences between positive and negative loading directions.

(c) For torque loading, the largest strain was measured by gauge 30SE at the rear of the root rib.

(d) Fin spar gauges have significant response and show considerable hysteresis. The longerons have insignificant response.

(e) Tailplane spar gauges 37BE and 38BE are more responsive to up than down loading.

APPENDIX 1. PROCEDURE FOR DERIVING STRAINS DUE TO PURE TORQUE

As noted in the text, strains due to pure torque have been derived from the wing torque loading case by correcting for the effect of bending. The procedure was as follows:-

1. Using figure 7, which is the spanwise bending moment distribution due to a 4g load increment (200% m.c.l.) applied in the wing bending load case, obtain the bending moment at the spanwise station for a strain gauge. Note the corresponding mean increment in strain, (as defined in section 4.1), and hence obtain the strain per unit bending moment.

2. Figure 8 gives the spanwise distributions of bending moment, (incremented from the 1.0g condition), applied during the torque loading case for both nose-down and nose-up directions. Use this figure for nose-up and nose-down loading separately, to obtain the bending moment at the strain gauge station for the torque loading.

3. Multiply this bending moment by the strain per unit bending moment from step 1 to give the strain due to bending.

4. Subtract the bending strain from the strain measured in the loading phase of the torque loading case, thereby giving the derived strain increment due to pure torque.

This procedure can be expressed as

$$e_t = e'_t - M_t . e_b / M_b$$

where e_t = strain due to pure torque

e'_t = measured strain in torque loading case

M_t = incremental bending moment, (from 1.0g condition), in torque loading case

M_b = bending moment due to 200% m.c.l. in wing bending case

e_b = strain increment due to M_b

The procedure was used for deriving strains due to pure torque at all wing strain gauges for the 100% nose-up and nose-down torque loading cases. The results are given in Table 7.

TABLE 1

SUMMARY OF CALIBRATION LOADING

Load Case No.	Load Case Description	Cal'bn Sign Conv'n	100% Maximum Calibrated Load (m.c.l.)	No. of Runs	No. of Load Levels	
					Ldg.	Unldg.
101	Wing Bending Down Load	-	240 kg deadweight hung on each wing through hangers (nominally -1g)	3	-	9
102	Wing Bending Up Load	+	954 kg applied to each wing through whiffle tree (nominally +3g)	3	9	-
103	Wing Torque Nose Up	-	102.14 kgf.m applied at the root rib	4	6	5
104	Wing Torque Nose Down	+	131.49 kgf.m applied at the root rib	4	6	5
305	Fin Load to Port	-	45.4 kg at the top rudder hinge point	3	6	5
306	Fin Load to St'bd	+	45.4 kg at the top rudder hinge point	3	6	5
207	Down Loading of Tailplane	-	113.4 kg -(56.7 kg at each outboard hinge point)	2	6	5
208	Up Loading of Tailplane	+	113.4 kg -(56.7kg at each outboard hinge point)	2	6	5

TABLE 2
DIRECTORY OF TRANSDUCER/STRAIN GAUGES

	CH.	QUANTITY	RANGE	TRANSDUCER	
	1	VERT ACCEL	+-10G	KISTLER QA110054	
	2	LAT ACCEL	+-2G	SCHAEVITZ LSB585	
	3	LONG ACCEL	+-2G	SCHAEVITZ	
	4	ROLL RATE	300 DEG/SEC	HONEYWELL GG4457	
	5	PITCH RATE	30 DEG/SEC	HONEYWELL GG4456	
	6	YAW RATE	100 DEG/SEC	HONEYWELL GG4457	
	7	INCIDENCE	360 DEG	ARL	
	8	SIDESLIP	360 DEG	ARL	
	9	PT FWD ACCEL	+-10G	KISTLER QA110054	
	10	PT AFT ACCEL	+-10G	KISTLER QA110054	
	11	STBD FWD ACCEL	+-10G	KISTLER QA110054	
	12	STBD AFT ACCEL	+-10G	KISTLER QA110054	
	13	NOSE ACCEL	+-10G	KISTLER QA110054	
	14	TAIL ACCEL	+-10G	KISTLER QA110054	
	15	FIN TIP ACCEL	+-10G	KISTLER QA110054	
STRAIN GAUGES	16	SG 5 BE WING BEND - MAIN SPAR WS 72 (1829MM)			PORT WING
	17	SG 9 BE WING BEND - MAIN SPAR WS 42 (1067MM)			" "
	18	SG 21 SE WING SHEAR - FRONT SPAR WS 26 (660MM)			" "
	19	SG 27 BE WING BEND - ROOT RIB FS 93 (2362MM)			" "
	20	SG 2 BE WING BEND - MAIN SPAR WS 112 (2845MM)			STBD WING
	21	SG 4 BE WING BEND - REAR SPAR WS 112 (2845MM)			" "
	22	SG 6 BE WING BEND - MAIN SPAR WS 72 (1829MM)			" "
	23	SG 8 BE WING BEND - REAR SPAR WS 72 (1829MM)			" "
	24	SG 10 BE WING BEND - MAIN SPAR WS 42 (1067MM)			" "
	25	SG 12 BE WING BEND - REAR WS 14 (356MM)			" "
	26	SG 57 BE PORT FLAP			
	27	SG 58 BE ST'BD FLAP			
	28	SG 18 CE WING COMP - REAR SPAR WS 42 (1067MM)			
	29	SG 20 TE WING TENS - REAR SPAR WS 42 (1067MM)			
	30	SG 22 SE WING SHEAR - FRONT SPAR WS 26 (660MM)			
	31	SG 24 SE WING SHEAR - REAR SPAR WS 24 (610MM)			
	32	SG 26 SE WING SHEAR - ROOT RIB FS 71 (1803MM)			
	33	SG 28 BE WING BEND - ROOT FS 93 (2362MM)			
	34	SG 30 SE WING SHEAR - ROOT RIB FS 112 (2845MM)			
	35	SG 32 RA WING SHEAR WS 25 FS 93 (2362MM)			
	36	SG 32 RB WING SHEAR WS 25 FS 93 (2362MM)			
	37	SG 32 RC WING SHEAR WS 25 FS 93 (2362MM)			
	38	SG 33 TE FIN TENSION - MAIN SPAR ROOT			PORT SIDE
	39	SG 34 TE FIN TENSION - MAIN SPAR ROOT			STBD SIDE
	40	SG 36 BE TAILPLANE BEND - MAIN SPAR TS 35 (889MM)			STBD
	41	SG 37 BE TAILPLANE BEND - MAIN SPAR TS 8 (203MM)			PORT
	42	SG 38 BE TAILPLANE BEND - MAIN SPAR TS 8 (203MM)			STBD
	43	SG 55 BE BENDING-PITCH INPUT (STICK)			
	44	SG 51 CE FUSE LONG-LH LOWER			
	45	SG 52 CE FUSE LONG-RH LOWER			
	46	SG 53 TE FUSELAGE LONG-LH UPPER			
	47	SG 54 TE FUSELAGE LONG-RH UPPER			
	48	DIGITAL L.S.M.			
	49	ANALOG L.S.M.			
	50	PHASE/EVENT MARKER			

TABLE 3

STRAIN CALIBRATION FACTORS

CHANNEL NO.	STRAIN GAUGE	STRAIN CAL'BN FACTOR
16	5BE	Ø.8388
17	9BE	1.1145
18	21SE	Ø.48Ø6
19	27BE	Ø.46Ø2
2Ø	2BE	Ø.579Ø
21	4BE	Ø.58Ø8
22	6BE	Ø.8443
23	8BE	Ø.5818
24	1ØBE	1.1151
25	12BE	1.3382
26 - 27	-	-
28	18CE	Ø.5816
29	2ØTE	Ø.5618
3Ø	22SE	Ø.4797
31	24SE	Ø.4522
32	26SE	Ø.4752
33	28BE	Ø.4615
34	30SE	Ø.4749
35	32RA	Ø.4791
36	32RB	Ø.4771
37	32RC	Ø.4796
38	33TE	1.1511
39	34TE	1.1591
4Ø	36BE	Ø.5866
41	37BE	1.1232
42	38BE	1.12Ø8
43	55BE	Ø.3Ø56
44	51CE	Ø.5662
45	52CE	Ø.5621
46	53TE	Ø.5565
47	54TE	Ø.56Ø8

TABLE 4

STRAIN RESPONSES FOR WING BENDING

STRAIN GAUGE	RUN CH	INCREMENTAL MICROSTRAIN DERIVED FROM REGR. LINE							AVERAGE MAXIMUM-MINIMUM MICROSTRAIN	STRAIN GAUGE
		1		2		3		AVERAGE		
		(-1 TO +1g)	(+1 TO + 3g)	(-1 TO +1g)	(+1 TO +3g)	(-1 TO +1g)	(+1 TO +3g)	(-1 TO +3g)	(-1 TO +3g)	
2BE	2Ø	149.1	133.4	148.3	134.1	147.2	131.6	281	282	2BE
4BE	21	118.5	129.1	119.2	128.4	118.2	129.3	248	246	4BE
5BE	16	362.8	381.5	365.8	379.Ø	364.Ø	38Ø.4	745	746	5BE
6BE	22	369.1	357.5	366.2	358.2	369.8	354.9	725	722	6BE
8BE	23	241.1	239.3	241.8	239.8	242.9	237.7	481	478	8BE
9BE	17	431.1	435.2	436.1	431.2	434.6	433.2	867	867	9BE
1ØBE	24	423.1	419.9	418.3	419.6	423.Ø	417.8	841	84Ø	1ØBE
12BE	25	599.5	6Ø1.Ø	594.4	597.5	6ØØ.2	595.3	1196	1196	12BE
18CE	28	-15.6	-47.8	-17.9	-45.2	-13.1	-47.5	-62	-64	18CE
2ØTE	29	198.7	199.5	197.7	198.8	199.7	198.6	398	4ØØ	2ØTE
21SE	18	-59.7	-68.Ø	-57.8	-67.9	-59.5	-68.3	-127	-128	21SE
22SE	3Ø	-12Ø.1	-112.9	-123.2	-113.9	-116.2	111.4	-233	234	22SE
24SE	31	51.7	63.Ø	53.7	61.5	55.3	62.5	116	118	24SE
26SE	32	-197.7	-18Ø.4	-192.4	-181.6	-198.3	-178.Ø	-376	-374	26SE
27BE	19	-139.2	-162.Ø	-142.1	-159.4	-143.9	-163.9	-3Ø4	-3Ø2	27BE
28BE	33	169.4	175.4	-161.6	-18Ø.Ø	-172.Ø	-175.Ø	345	344	28BE
3ØSE	34	156.Ø	151.5	-149.8	156.5	-149.5	-149.5	-3Ø4	-3Ø3	3ØSE
32RA	35	179.6	161.1	183.1	162.3	181.8	157.8	342	351	32RA
32RB	36	178.9	188.4	185.5	189.6	182.4	189.2	371	375	32RB
32RC	37	147.3	-186.6	-143.1	-188.9	-149.7	-184.Ø	-333	-343	32RC

<u>TABLE 5 (a)</u>

<u>MEASURED MICROSTRAIN RESPONSES FOR WING TORQUE CASE-NOSE-UP LOADING PHASE</u>

		100% INCREMENT DERIVED FROM REGRESSION LINE					
STRAIN GAUGE	CH \ RUN	1	2	3	4	ALL RUNS	MICROSTRAIN /100 kgf.m
5BE	16	126	126	128	127	127.1	125
9BE	17	129	129	133	132	130.7	128
21SE	18	-11	-12	-7.5	- 9	- 9.8	-10
27BE	19	- 8.7	- 8.1	-17	-17	-12.6	-12
2BE	20	51	49	52	52	51.2	50
4BE	21	42	40	40	39	40.4	40
6BE	22	121	124	115	118	119.5	117
8BE	23	99	100	103	94	98.9	97
10BE	24	126	130	118	121	123.7	121
12BE	25	151	155	138	140	145.7	143
18CE	28	-62	-63	-59	-59	-60.6	-59
20TE	29	118	119	112	116	116.4	114
22SE	30	-23	-20	-24	-21	-22.0	-22
24SE	31	16	17	15	15	15.9	16
26SE	32	-44	-48	-31	-34	-39.0	-38
28BE	33	- 3.2	- 7	5	2	- 0.8	- 1
30SE	34	45	47	53	55	49.9	49
32RA	35	39	40	32	32	35.8	35
32RB	36	25	25	22	22	23.5	23
32RC	37	-10	-14	1	- 3	- 6.5	- 6

TABLE 5 (b)

MEASURED MICROSTRAIN RESPONSES FOR WING TORQUE CASE -NOSE-UP UNLOADING PHASE

STRAIN GAUGE	CH (RUN)	100% INCREMENT DERIVED FROM REGRESSION LINE * 1	2	3	4	ALL RUNS	MICROSTRAIN /1ØØ kgf.m
5BE	16	116	112	115	112	114.Ø	112
9BE	17	125	122	127	124	124.5	122
21SE	18	-13	-12	-1Ø	-1Ø	-11.3	-11
27BE	19	- 5	- 7	- 9	- 8	- 7.Ø	- 7
2BE	2Ø	46	47	49	5Ø	48.Ø	47
4BE	21	43	42	43	42	42.4	42
6BE	22	116	111	11Ø	1Ø9	111.3	1Ø9
8BE	23	98	99	1Ø3	96	98.8	97
10BE	24	12Ø	112	114	11Ø	114.0	112
12BE	25	149	14Ø	139	135	14Ø.8	138
18CE	28	-65	-64	-61	-62	-62.9	-62
20TE	29	93	89	9Ø	88	89.8	88
22SE	3Ø	-19	-19	-19	-2Ø	-18.9	-19
24SE	31	18	16	17	17	17.Ø	17
26SE	32	-49	-43	-36	-37	-41.3	-41
28BE	33	- 1	7	3	7	4.Ø	4
30SE	34	54	61	58	59	57.9	57
32RA	35	76	71	67	69	7Ø.8	69
32RB	36	42	37	39	4Ø	39.3	39
32RC	37	-15	- 8	- 6	- 6	- 9.Ø	- 9

* FOR UNLOADING THIS LINE WAS FITTED TO DATA FROM 80% - 0%.

TABLE 5 (c)

MEASURED MICROSTRAIN RESPONSES FOR WING TORQUE CASE-NOSE-DOWN LOADING PHASE

		100% INCREMENT DERIVED FROM REGRESSION LINE					
STRAIN GAUGE	CH \ RUN	1	2	3	4	ALL RUNS	MICROSTRAIN /1ØØ kgf.m
5BE	16	-19	-17	-16	-15	-16.9	-13
9BE	17	- 4	1	- 1	- 2	- 1.4	- 1
21SE	18	-19	-21	-22	-23	-21.Ø	-16
27BE	19	-21	-25	-2Ø	-22	-21.7	-17
2BE	2Ø	-18	-18	-18	-2Ø	-18.3	-14
4BE	21	-4Ø	-4Ø	-4Ø	-44	-4Ø.9	-31
6BE	22	-2Ø	-16	-11	-11	-14.6	-11
8BE	23	-19	-16	-14	-16	-16.3	-12
10BE	24	- 9	- 5	1	2	- 2.8	- 2
12BE	25	-14	- 7	3	- 3	- 5.4	- 4
18CE	28	17	19	19	19	18.7	+14
20TE	29	-28	-33	-35	-2Ø	-29.Ø	-22
22SE	3Ø	-27	-29	-33	-27	-28.9	-22
24SE	31	- 9	- 7	- 9	- 9	- 8.2	- 6
26SE	32	51	49	4Ø	42	45.7	+35
28BE	33	-21	-27	-34	-37	-29.6	-23
30SE	34	-63	-62	-74	-72	-67.5	-51
32RA	35	- 6	- 3	5	- 6	- 2.3	- 2
32RB	36	35	35	37	24	32.5	+25
32 RC	37	-13	-18	-27	-27	-21.Ø	-16

TABLE 5 (d)

MEASURED MICROSTRAIN RESPONSES FOR WING TORQUE CASE-NOSE-DOWN UNLOADING PHASE

STRAIN GAUGE	CH \ RUN	1	2	3	4	ALL RUNS	MICROSTRAIN /1ØØ kgf.m
		100% INCREMENT DERIVED FROM REGRESSION LINE *					
5BE	16	-18	-18	-13	-21	-17.5	-13
9BE	17	- 3	- 2	1	- 6	- 2.5	- 2
21SE	18	-18	-19	-22	-2Ø	-19.6	-15
27BE	19	-13	-13	- 9	- 9	-1Ø.9	- 8
2BE	2Ø	-19	-18	-22	-19	-19.4	-15
4BE	21	-4Ø	-4Ø	-4Ø	-38	-39.2	-3Ø
6BE	22	-18	-17	-14	-11	-15.Ø	-11
8BE	23	-17	-18	-16	- 9	-14.8	-11
10BE	24	- 5	- 5	1	- 1	- 2.2	- 2
12BE	25	-11	- 8	- 4	- 3	- 6.5	- 5
16CE	28	12	13	13	13	12.8	+1Ø
20TE	29	-33	-45	-46	-49	-43.3	-33
22SE	3Ø	-2Ø	-24	-24	-22	-22.4	-17
24SE	31	- 5	- 6	- 7	- 5	- 5.8	- 4
26SE	32	5Ø	49	43	38	45.Ø	+34
28BE	33	-11	-13	-19	-17	-14.9	-11
30SE	34	-58	-64	-67	-62	-62.9	-48
32RA	35	-19	-17	-19	- 5	-14.9	-11
32RB	36	27	27	24	28	26.1	+2Ø
32RC	37	- 6	-1Ø	-12	-2Ø	-11.8	-23

* FOR UNLOADING THIS LINE WAS FITTED TO DATA FROM 80% - 0%

TABLE 6 (a)

CHANGE OF OFFSET - WING TORQUE CASE - NOSE UP

		MICROSTRAIN				
STRAIN GAUGE	RUN / CH	1	2	3	4	AVERAGE
5BE	16	1∅.3	1∅.8	14.3	13.5	12.2
9BE	17	3.8	1.2	7.9	6.8	4.9
21SE	18	1.1	-1.5	3.1	2.∅	1.2
27BE	19	∅.2	4.3	-1∅.4	-7.1	-3.3
2BE	2∅	4.8	2.6	3.9	2.2	3.4
4BE	21	-1.8	-2.7	-4.4	-4.∅	-3.2
6BE	22	7.8	13.4	7.3	8.1	9.2
8BE	23	-1.4	1.1	-1.5	-2.5	-1.1
1∅BE	24	9.7	18.9	8.∅	1∅.1	11.7
12BE	25	4.∅	13.2	1.4	2.1	5.2
18CE	28	-1.8	-1.7	-2.9	-2.2	-2.2
2∅TE	29	24.1	26.8	24.3	27.∅	25.6
22SE	3∅	-4.4	1.2	-6.5	∅.4	-2.3
24SE	31	-3.6	-1.8	-3.3	-2.2	-2.7
26SE	32	2.1	-9.1	5.8	3.2	∅.5
28BE	33	-3.9	-15.1	∅.9	-3.1	-5.3
3∅SE	34	-13.2	-17.9	-6.7	-2.1	-1∅.∅
32RA	35	-41.∅	-36.1	-38.7	-38.2	-38.5
32RB	36	-21.7	-18.9	-2∅.2	-2∅.5	-2∅.3
32RC	37	5.∅	-5.6	8.7	4.4	3.1

TABLE 6 (b)

CHANGE OF OFFSET - WING TORQUE CASE - NOSE DOWN

		MICROSTRAIN				
STRAIN GAUGE	RUN / CH	1	2	3	4	AVERAGE
5BE	16	-1.9	1.9	-2.9	2.5	-0.1
9BE	17	-1.9	3.8	-1.6	-0.4	0.0
21SE	18	-2.8	-4.6	-2.9	-7.1	-4.3
27BE	19	-9.0	-12.3	-11.2	-12.3	-11.2
2BE	20	1.4	1.7	4.2	0.4	1.9
4BE	21	-0.7	0.4	-1.1	-5.9	-1.8
6BE	22	-1.2	2.0	0.8	-1.9	-0.1
8BE	23	-7.7	-3.5	-4.8	-8.7	-6.2
10BE	24	-1.8	2.9	-0.1	0.2	0.3
12BE	25	1.0	6.4	6.7	-2.2	3.0
18CE	28	6.8	6.6	8.6	11.3	8.3
20TE	29	-5.7	-1.8	5.1	2.9	0.1
22SE	30	-10.3	-7.4	-12.5	-4.1	-8.6
24SE	31	-2.4	0.5	-1.2	-1.5	-1.2
26SE	32	-0.2	-1.7	-0.2	4.5	0.6
28BE	33	-15.8	-18.4	-21.9	-23.9	-20.0
30SE	34	-11.7	6.2	-18.0	-16.0	-13.0
32RA	35	15.7	17.6	23.3	1.1	14.4
32RB	36	10.4	11.4	16.3	0.1	9.6
32RC	37	-10.6	-13.3	-18.9	-13.6	-14.1

TABLE 7

DERIVED STRAIN RESPONSES FOR PURE WING TORQUE

STRAIN GAUGE	CHANNEL NO.	MICROSTRAIN NOSE DOWN 100% m.c.l.	MICROSTRAIN NOSE DOWN Microstrain /100 kgf.m	MICROSTRAIN NOSE UP 100% m.c.l.	MICROSTRAIN NOSE UP Microstrain /100 kgf.m
5BE	16	2	2	-9	-9
9BE	17	2	2	-18	-18
21SE	18	-21	-16	8	8
27BE	19	-22	-17	26	26
2BE	20	-4	-3	-5	-5
4BE	21	-28	-22	-9	-9
6BE	22	1	1	-12	-12
8BE	23	-6	-5	12	12
10BE	24	-1	-1	-21	-21
12BE	25	-6	-5	8	8
18CE	28	20	15	-50	-49
20TE	29	-28	-21	48	47
22SE	30	-29	-22	10	10
24SE	31	-8	-6	0	0
26SE	32	46	35	11	11
28BE	33	-29	-22	44	43
30SE	34	-66	-51	91	89
32RA	35	-2	-2	-11	-11
32RB	36	33	25	-27	-27
32RC	37	-21	-16	40	39

TABLES 8 (a) AND (b)

MICROSTRAIN RESPONSES - FIN LOADING TO PORT

(a) LOADING PHASE

		100% INCREMENT DERIVED FROM REGR. LINE				
STRAIN GAUGE	RUN / CN	1	2	3	ALL RUNS	MICROSTRAIN /100 kg
33TE	38	-347.3	-357.8	-359.2	-355	-785
34TE	39	333.2	343.8	346.2	341	754
51CE	44	-19.2	-21.2	-15.6	-18.7	-41
52CE	45	16.1	17.2	15.7	16.4	36
53TE	46	10.3	9.7	10.7	10.3	23
54TE	47	-8.1	-8.4	-9.8	-8.8	-19

(b) UNLOADING PHASE

		100% INCREMENT DERIVED FROM REGR. LINE*				
STRAIN GAUGE	RUN / CN	1	2	3	ALL RUNS	MICROSTRAIN /100 kg
33TE	38	-312.8	-347.1	-344.2	-334	-738
34TE	39	294.9	322.8	320.5	312	690
51CE	44	-10.7	-12.7	-15.3	-12.9	-29
52CE	45	16.8	19.7	19.4	18.6	41
53TE	46	7.5	9.2	9.2	8.6	19
54TE	47	-8.9	-9.3	-10.1	-9.4	-21

* FOR UNLOADING THIS LINE WAS FITTED TO DATA FROM 80% - 0%

TABLES 8 (c) AND (d)

MICROSTRAIN RESPONSES - FIN LOADING TO STARBOARD

(c) LOADING PHASE

STRAIN GAUGE	RUN / CH	100% INCREMENT DERIVED FROM REGR. LINE				MICROSTRAIN /100 kg
		1	2	3	ALL RUNS	
33TE	38	357.3	359.6	361.1	359	793
34TE	39	-391.4	-395.4	-396.6	-395	-873
51CE	44	13.3	12.1	13.8	13.0	29
52CE	45	-17.6	-17.7	-17.3	-17.6	-39
53TE	46	-11.4	-11.1	-10.5	-11.0	-24
54TE	47	10.3	10.2	9.5	10.0	22

(d) UNLOADING PHASE

STRAIN GAUGE	RUN / CH	100% INCREMENT DERIVED FROM REGR. LINE *				MICROSTRAIN /100 kg
		1	2	3	ALL RUNS	
33TE	38	337.9	339.0	339.6	339	749
34TE	39	-359.9	-363.4	-364.5	-363	-802
51CE	44	17.6	18.1	18.1	17.9	40
52CE	45	-19.4	-20.2	-18.8	-19.5	-43
53TE	46	-10.3	- 9.7	-9.2	-9.7	-21
54TE	47	8.4	7.9	8.1	8.1	18

TABLE 9 (a)

CHANGE OF OFFSET - FIN LOADING TO PORT

STRAIN GAUGE	RUN / CH	MICROSTRAIN 1	2	3	AVERAGE
33TE	38	-24.6	-26.1	-30.2	-27.0
34TE	39	30.4	31.5	36.7	32.9
51CE	44	-7.5	-6.4	-0.1	-4.7
52CE	45	-1.5	-3.2	-3.7	-2.8
53TE	46	2.6	1.7	2.8	2.4
54TE	47	0.9	0.2	-0.7	0.1

TABLE 9 (b)

CHANGE OF OFFSET - FIN LOADING TO STARBOARD

STRAIN GAUGE	RUN / CH	MICROSTRAIN 1	2	3	AVERAGE
33TE	38	30.0	30.5	32.5	31.0
34TE	39	-49.1	-49.0	-50.4	-49.5
51CE	44	-4.3	-6.2	-4.6	-5.0
52CE	45	2.5	2.6	2.3	2.5
53TE	46	-2.1	-2.1	-2.5	-2.2
54TE	47	2.8	2.9	1.7	2.5

TABLES 1Ø (a) AND (b)

MICROSTRAIN RESPONSES TO DOWNLOADS ON TAILPLANE

(a) LOADING PHASE

STRAIN GAUGE	RUN / CH	1ØØ% INCR'T DERIVED FROM REGR. LINE			MICROSTRAIN /1ØØ kg
		1	2	ALL RUNS	
36BE	40	-269.7	-269.8	-27Ø	-238
37BE	41	-395.Ø	-394.1	-395	-348
38BE	42	-411.7	-411.7	-412	-363
51CE	44	-56.4	-58.4	-57.4	-51
52CE	45	-61.2	-61.4	-61.3	-54
53TE	46	83.6	83.5	83.5	74
54TE	47	89.8	89.7	89.8	79

(b) UNLOADING PHASE

STRAIN GAUGE	RUN / CH	1ØØ% INCR'T DERIVED FROM REGR. LINE*			MICROSTRAIN /1ØØ kg
		1	2	ALL RUNS	
36BE	4Ø	-259.9	-259.9	-26Ø	-229
37BE	41	-377.4	-376.8	-377	-333
38BE	42	-388.9	-388.4	-389	-343
51CE	44	-52.4	-52.4	-52.4	-46
52CE	45	-6Ø.7	-6Ø.1	-6Ø.4	-53
53TE	46	83.2	82.6	82.9	73
54TE	47	86.6	86.4	86.5	76

* FOR UNLOADING THIS LINE WAS FITTED TO DATA FROM 80% - 0%.

TABLES 10 (c) AND (d)

MICROSTRAIN RESPONSES TO UPLOADS ON TAILPLANE

(c) LOADING PHASE

STRAIN GAUGE	RUN / CH	100% INCR'T. DERIVED FROM REGR. LINE			MICROSTRAIN /100 kg
		1	2	ALL RUNS	
36BE	40	274.0	278.1	276	243
37BE	41	454.9	457.0	456	402
38BE	42	471.7	474.1	473	417
51CE	44	48.8	48.4	48.6	43
52CE	45	56.4	57.3	56.8	50
53TE	46	-85.5	-86.6	-86.1	-76
54TE	47	-89.5	-90.5	-90.0	-79

(d) UNLOADING PHASE

STRAIN GAUGE	RUN / CH	100% INCR'T. DERIVED FROM REGR. LINE*			MICROSTRAIN /100 kg
		1	2	ALL RUNS	
36BE	40	249.3	253.7	252	222
37BE	41	439.7	443.1	441	389
38BE	42	448.9	453.4	451	398
51CE	44	50.1	51.2	50.7	45
52CE	45	57.1	58.2	57.6	51
53TE	46	-84.6	-86.3	-85.4	-75
54TE	47	-87.5	-88.3	-87.9	-78

* FOR UNLOADING THIS LINE WAS FITTED TO DATA FROM 80% - 0%

TABLE 11 (a)

CHANGE OF OFFSET - TAILPLANE DOWN LOADING

STRAIN GAUGE	RUN / CH	MICROSTRAIN 1	MICROSTRAIN 2
36BE	40	-4.8	-6.3
37BE	41	-12.9	-13.9
38BE	42	-20.6	-22.4
51CE	44	-4.8	-8.0
52CE	45	-0.1	-1.3
53TE	46	1.2	1.6
54TE	47	4.8	5.1

TABLE 11 (b)

CHANGE OF OFFSET - TAILPLANE UP LOADING

STRAIN GAUGE	RUN / CH	MICROSTRAIN 1	MICROSTRAIN 2
36BE	40	10.1	11.5
37BE	41	14.5	14.2
38BE	42	23.2	22.6
51CE	44	-0.1	-1.7
52CE	45	-0.4	-0.9
53TE	46	-1.2	-1.2
54TE	47	-3.9	-3.7

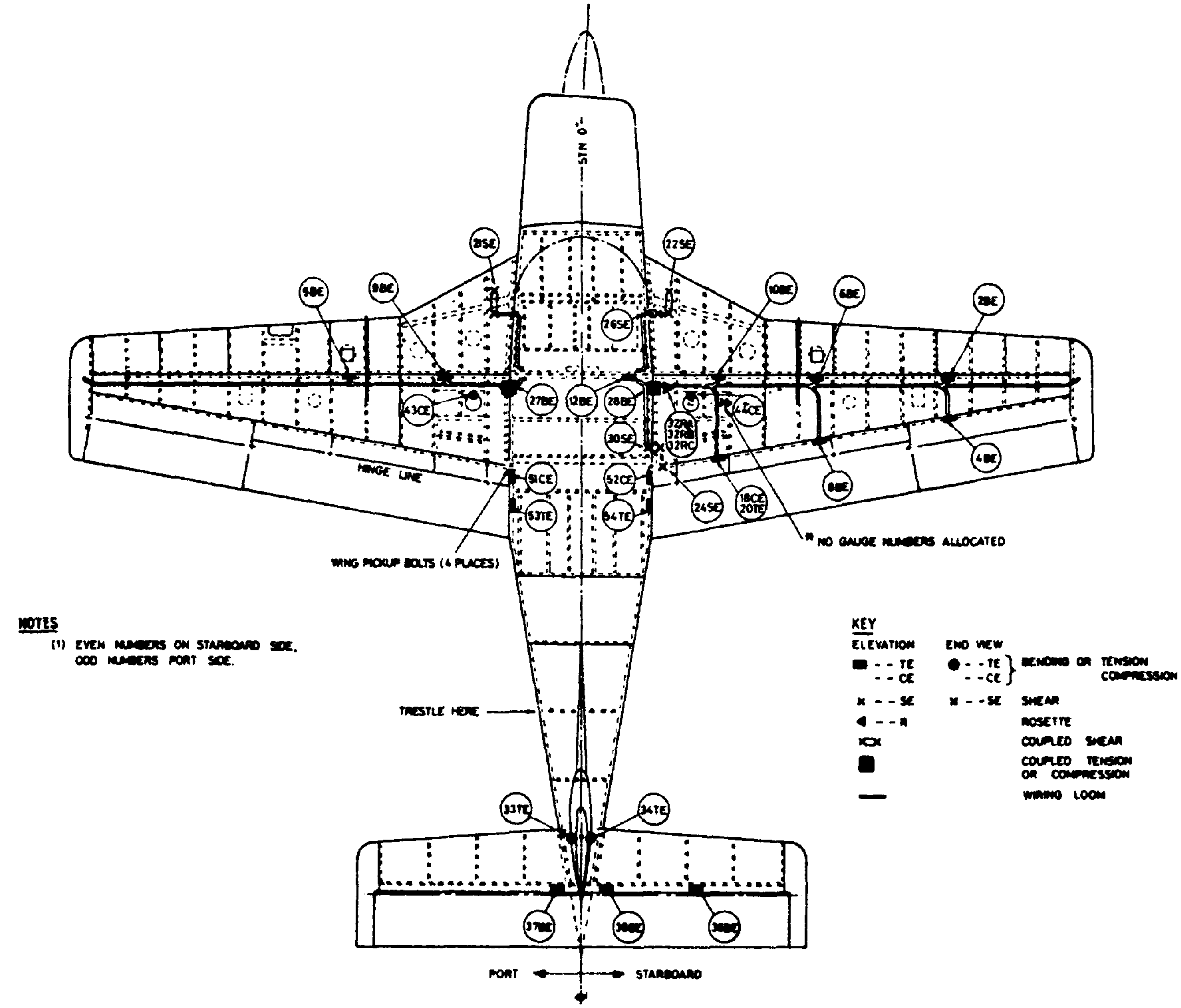

FIG 1 CT4A - PLAN SHOWING GAUGE POSITION

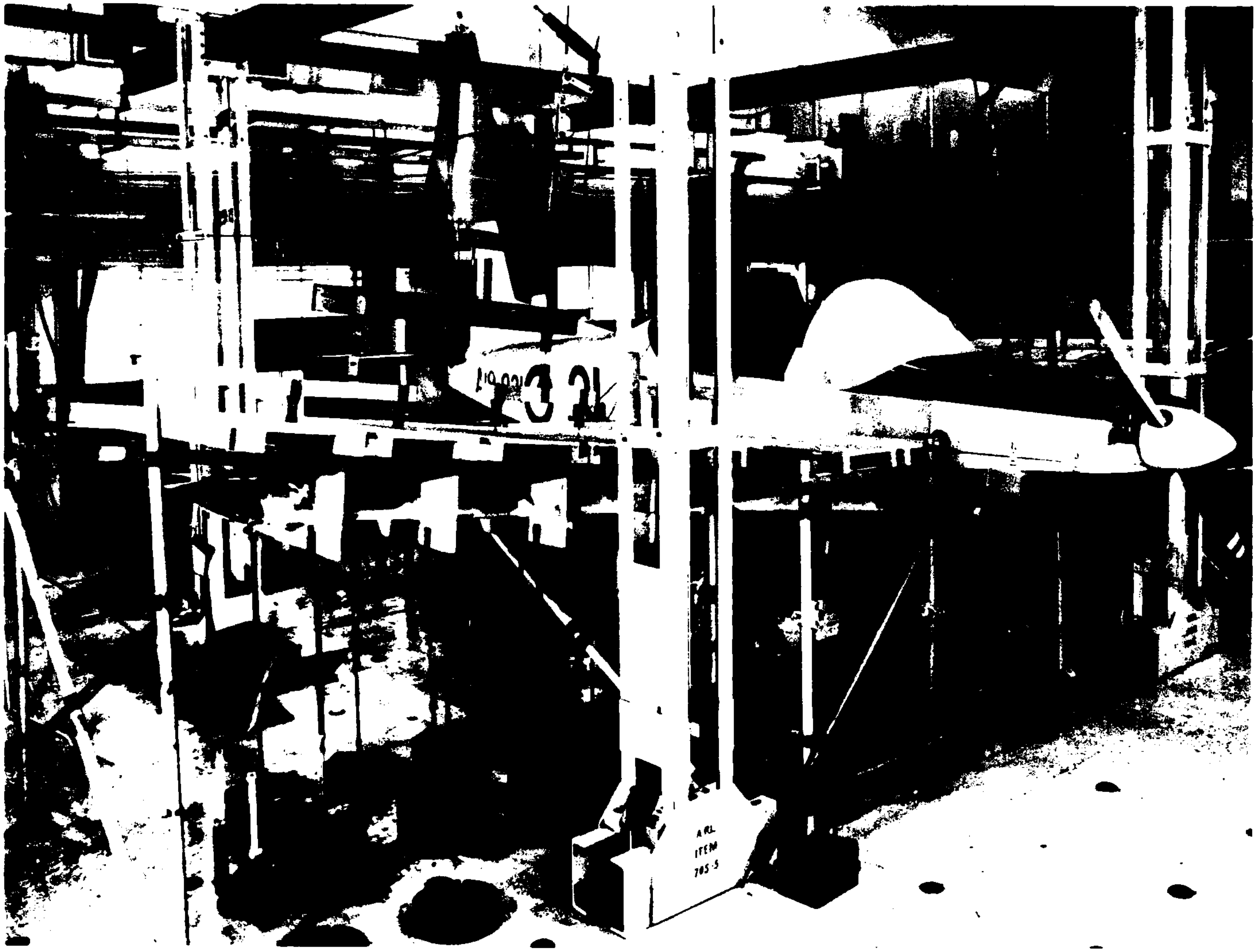

FIG. 2(a): CT4A—FRONT VIEW SHOWING LOADING RIG

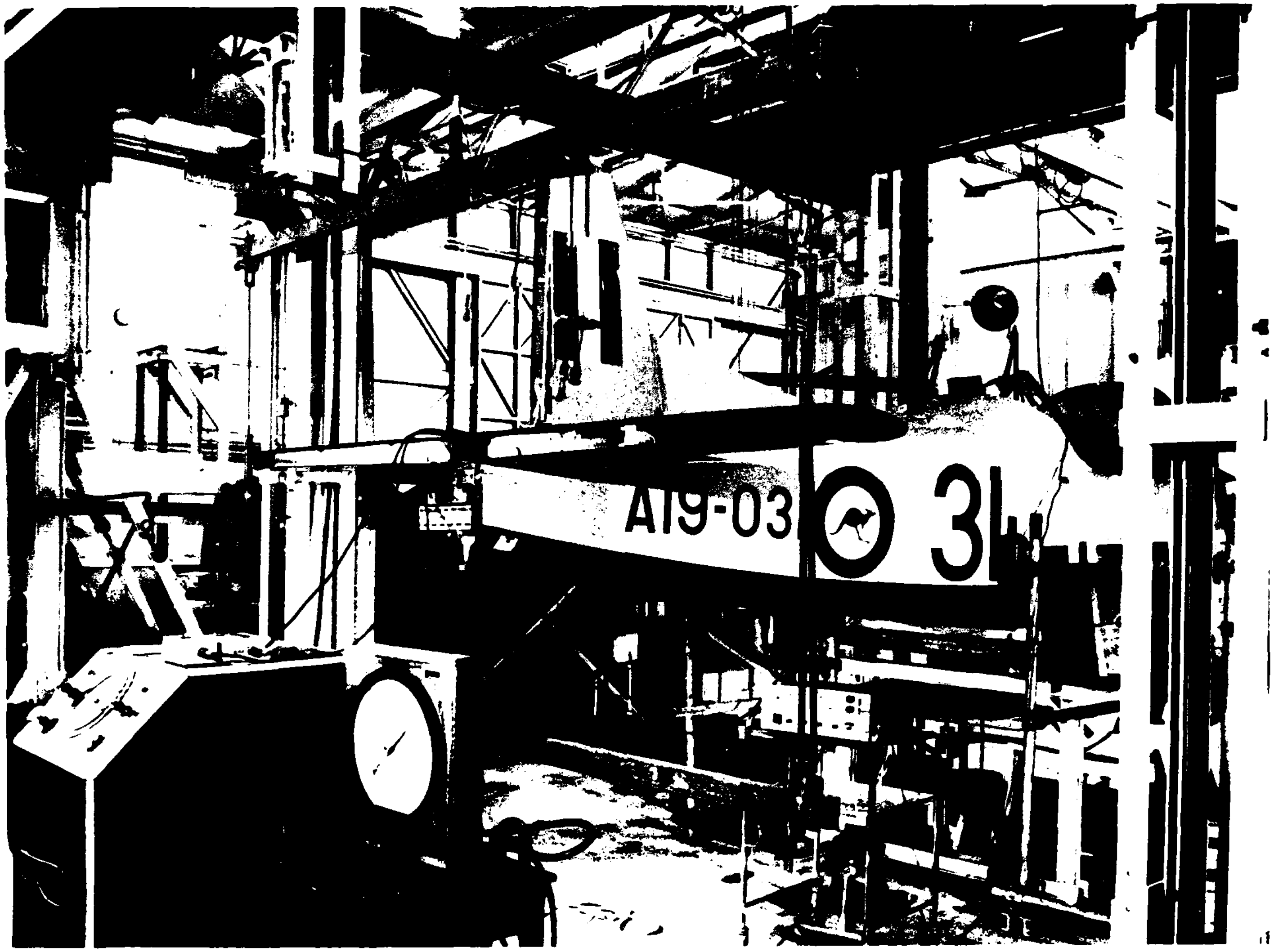

FIG. 2(b): CT4A—REAR VIEW SHOWING
TAIL-PLANE LOADING ASSEMBLY

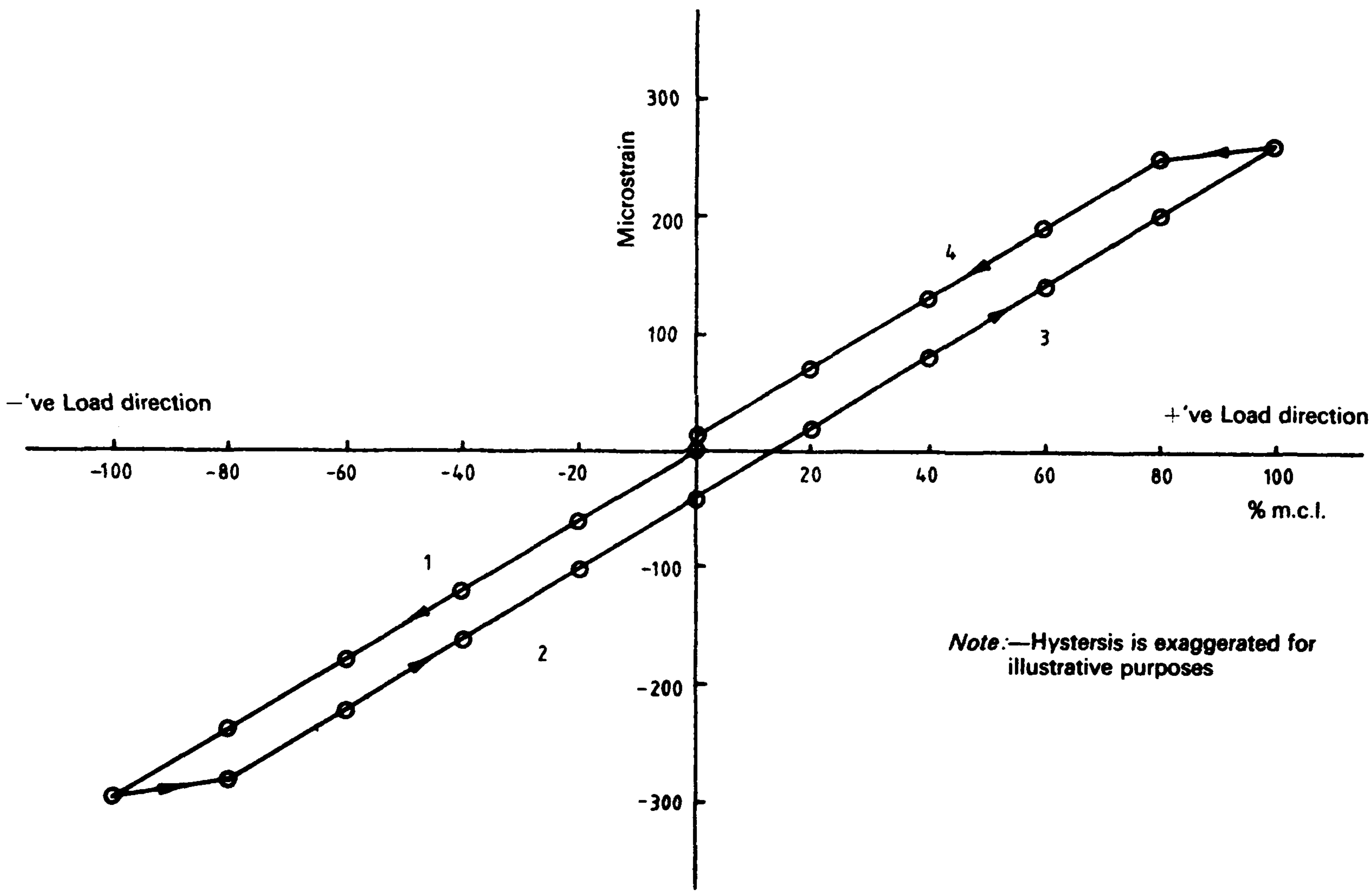

FIG. 3: ILLUSTRATION OF LOADING CASES

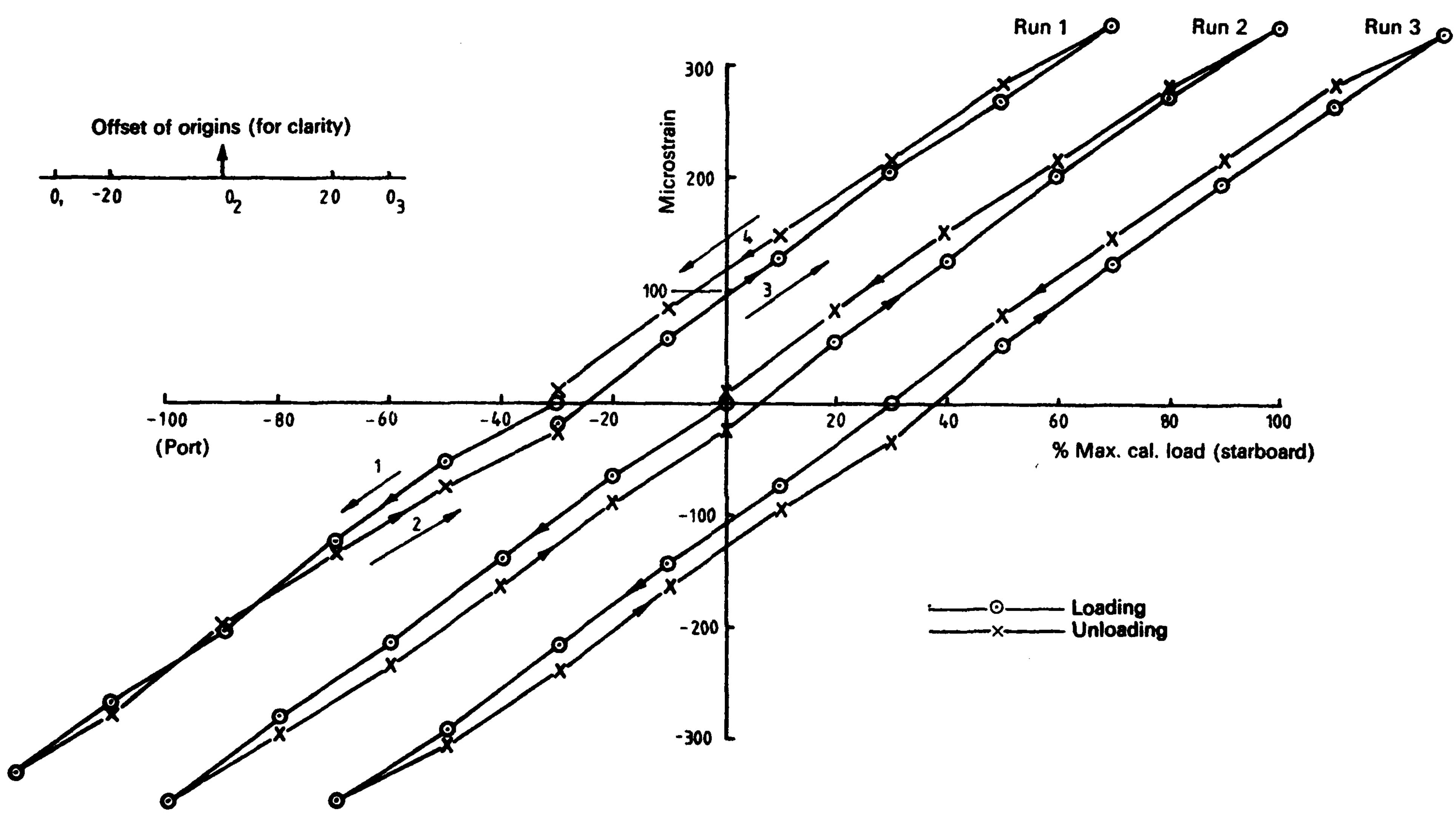

FIG. 4: FIN LOADING—HYSTERESIS EFFECT (CHANNEL 38—S.G. 33TE)

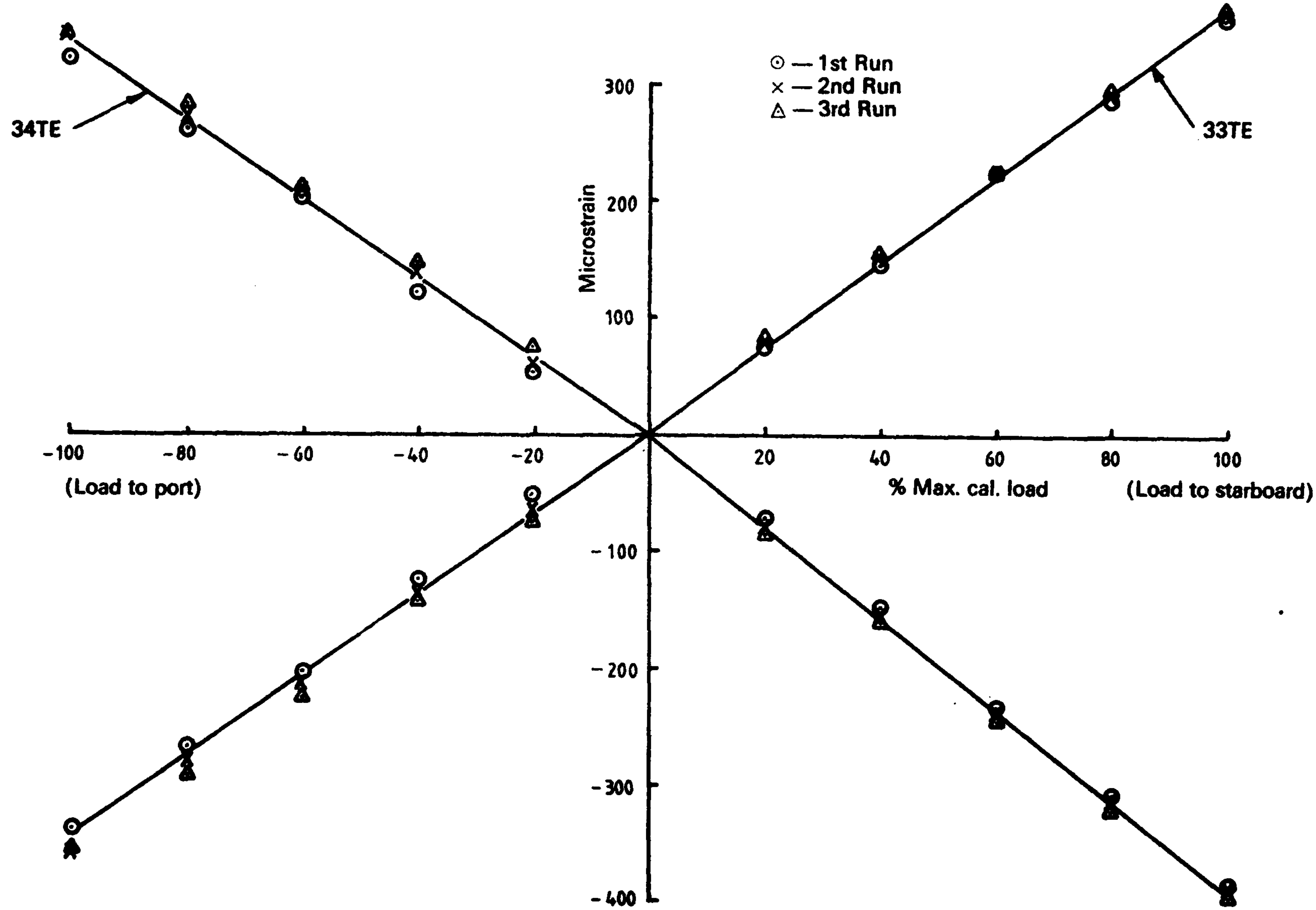

FIG. 5: STRAIN RESPONSE FOR FIN LOADING (LOADING PHASE ONLY)

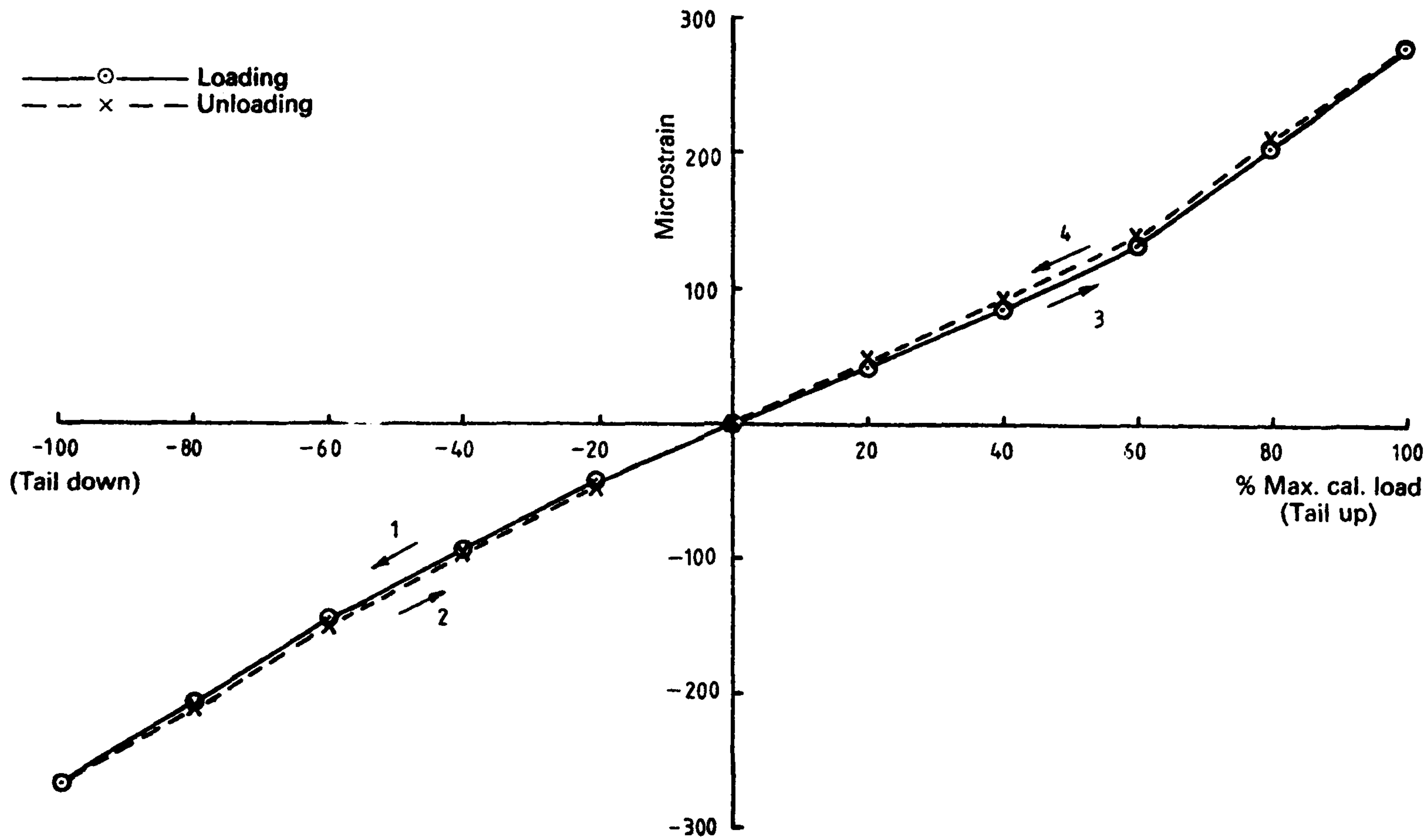

FIG. 6(a): STRAIN RESPONSE FOR TAIL-PLANE GAUGE 36BE

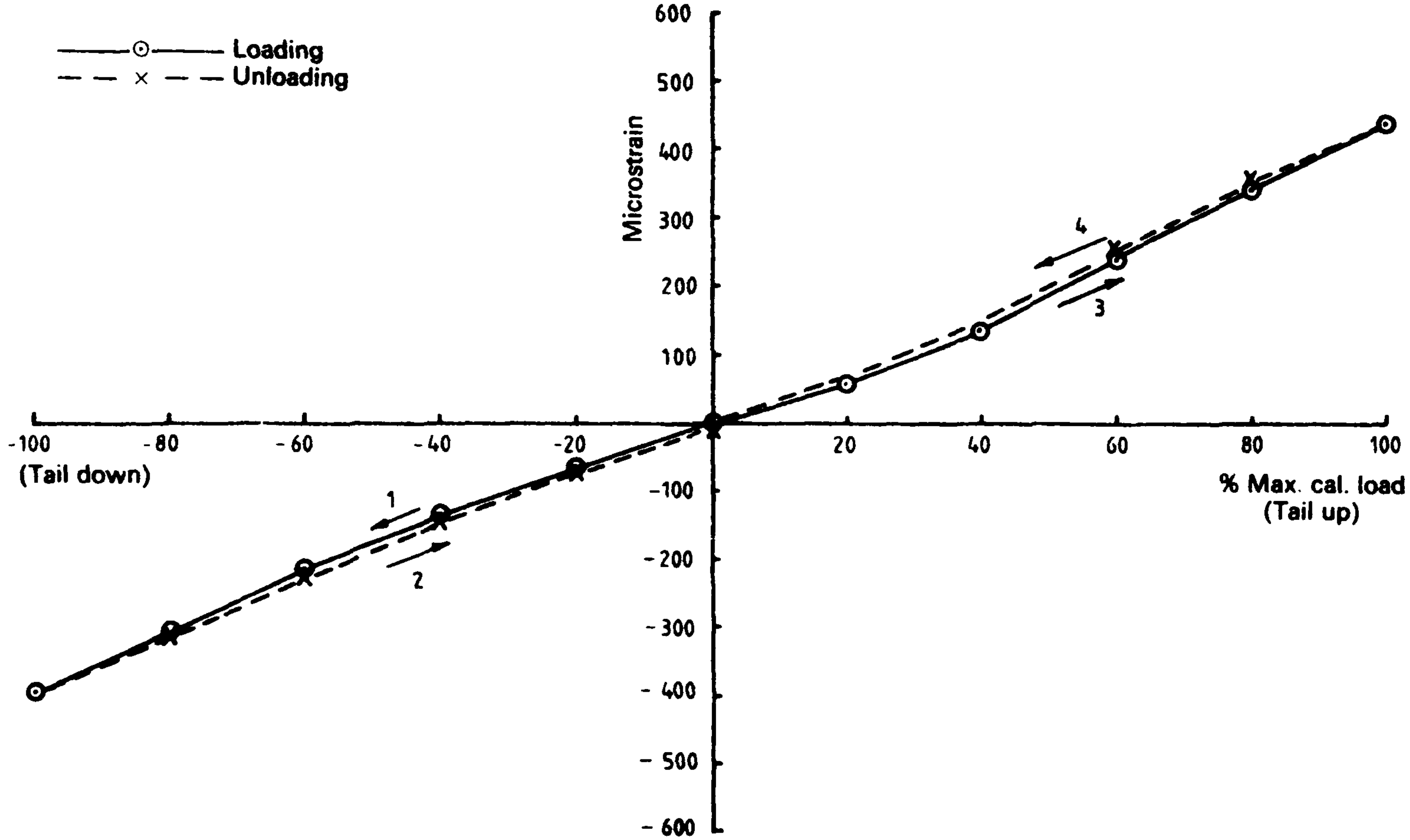

FIG. 6(b): STRAIN RESPONSE FOR TAIL-PLANE GAUGE 37BE

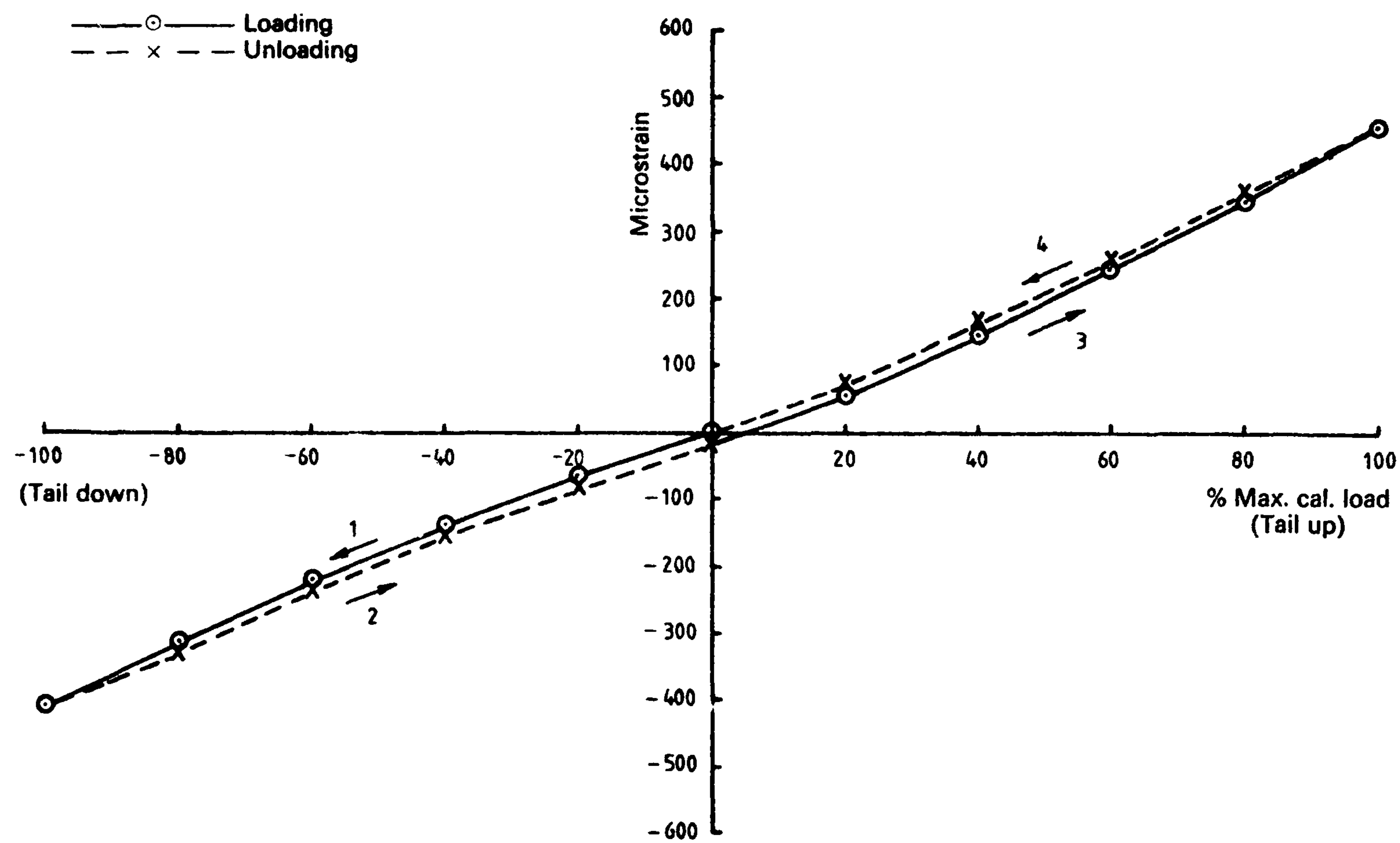

FIG. 6(c): STRAIN RESPONSE FOR TAIL-PLANE GAUGE 38BE

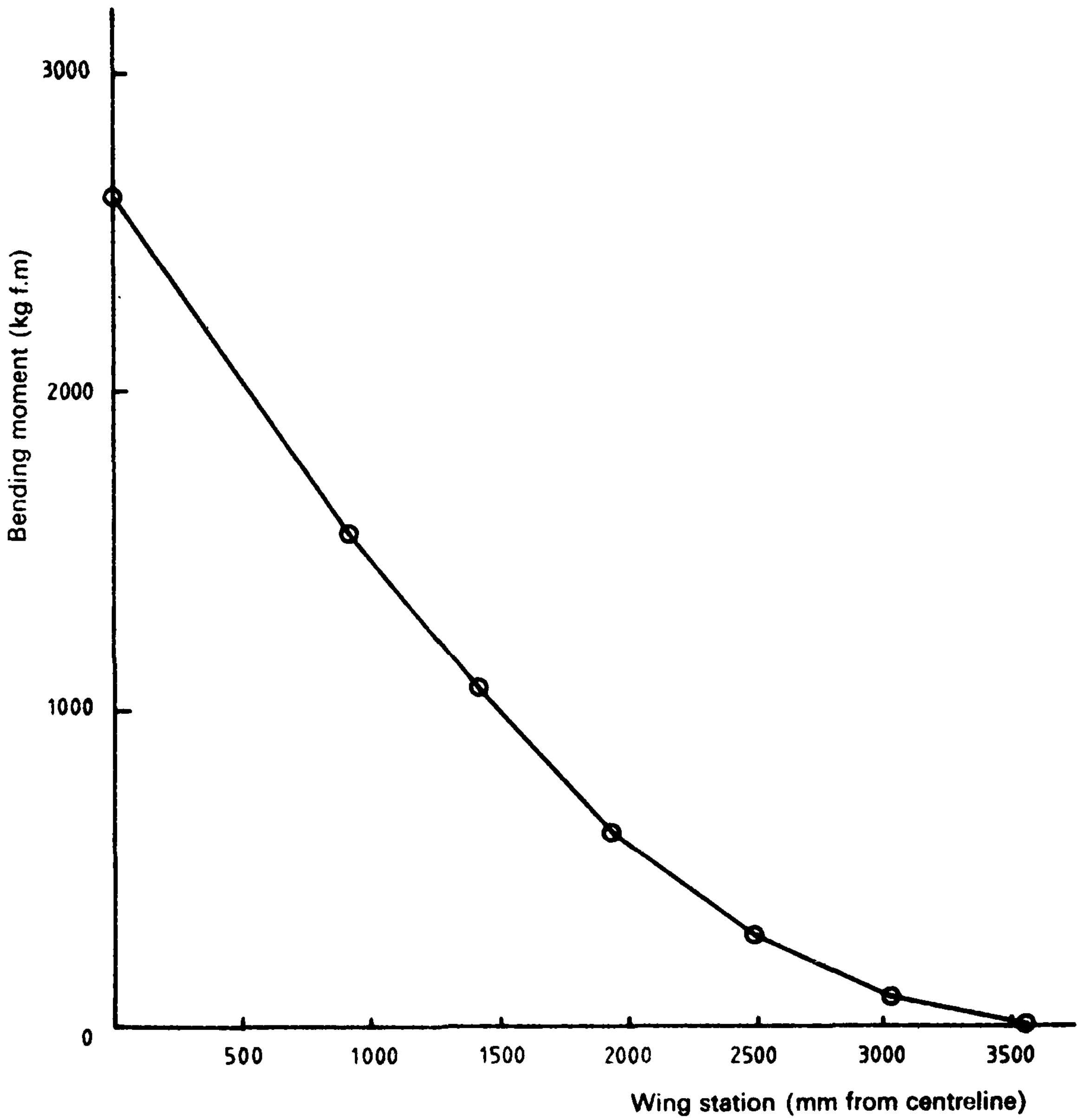

FIG. 7: SPANWISE BENDING MOMENT DISTRIBUTION DUE TO 200% m.c.l. FOR WING BENDING CASE

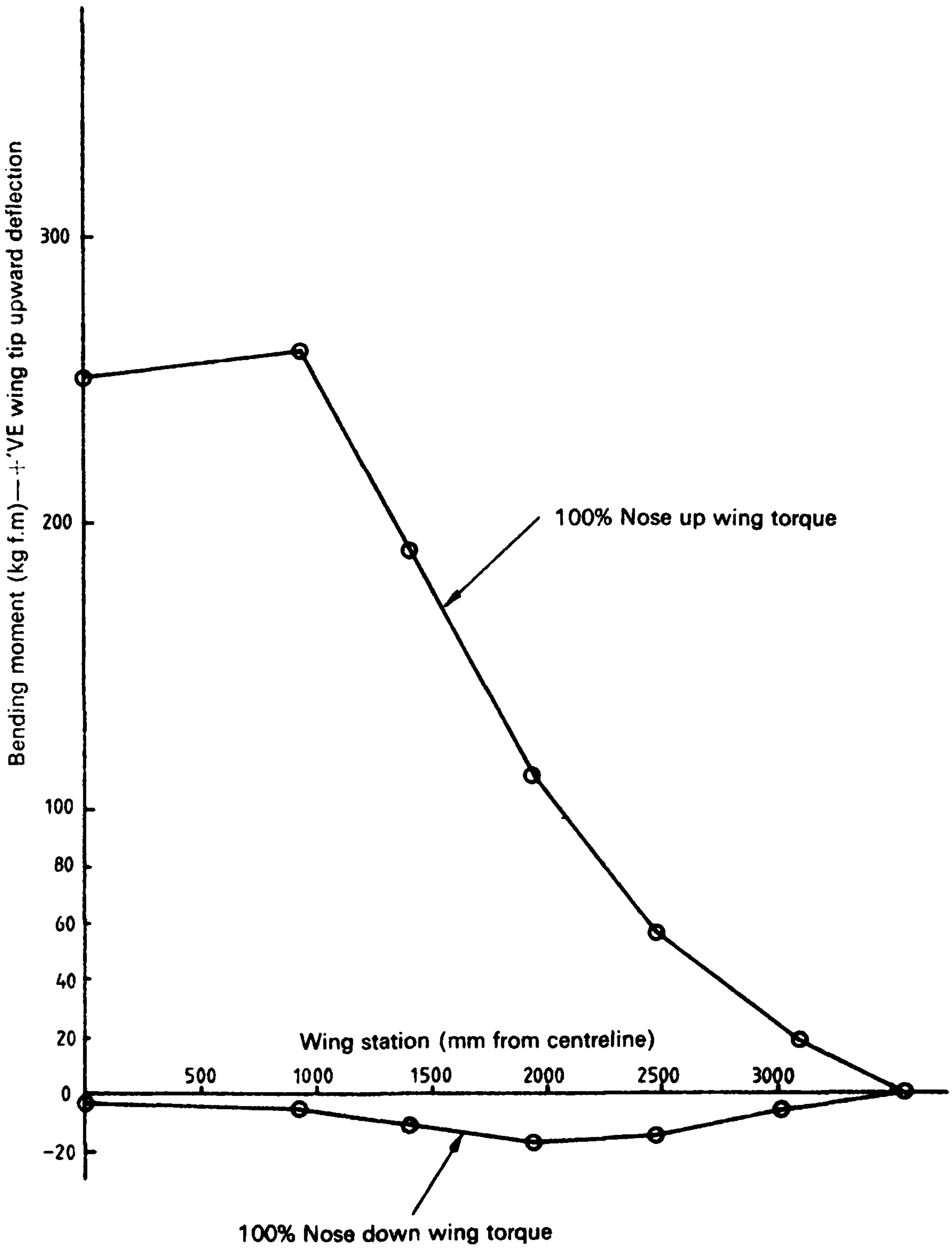

FIG. 8: SPANWISE BENDING MOMENT DISTRIBUTION DUE TO 100% m.c.l. FOR NOSE UP AND NOSE DOWN WING TORQUE CASES

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Joint Intelligence Organisation	6
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Aeronautical Research Laboratories	
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M.C.J. Higgs	28
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